ATTACHMENT G: WELL CONSTRUCTION AND TESTING

CTV II

Facility Information

Facility Name: CTV II

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Location: [redacted]

Introduction

CTV requires seven wells for injection and monitoring associated with this project including two injectors, three [redacted] wells, one above zone [redacted] well, and one USDW monitoring well. [redacted]. Figure 1 shows the identifies the wells proposed for the project.

[redacted]

Figure 1: Map showing the location of injection wells and monitoring wells.

All planned new wells will be constructed with components that are compatible with the injectate and formation fluids encountered such that corrosion rates and cumulative corrosion over the duration of the project are acceptable. The proposed well materials will be confirmed based on actual CO_2 composition such that material strength is sufficient to withstand all loads encountered throughout the life of the well with an acceptable safety factor incorporated into the design. Casing points will be verified by trained geologists using real-time drilling data such as LWD and mud logs to ensure non-endangerment of USDW. Due to the depth of the base of USDW, an intermediate casing string will be utilized to isolate the USDW. Cementing design, additives, and placement procedures will be sufficient to ensure isolation of the injection zone and protection of USDW using cementing materials that are compatible with injectate, formation fluids, and subsurface pressure and temperature conditions.

Appendix C-1: Injection and Monitoring Well Schematics provides casing diagram figures for all injection and monitoring wells with construction specifications and anticipated completion details in graphical and/or tabular format.

Injection wells will have wellhead equipment sufficient to shut off injection at surface. The project does not anticipate risk factors that warrant downhole shut-off devices, such as high temperature, high pressure, presence of hydrogen sulfide, proximity to populated areas, or high likelihood of damage to the wellhead.

Proposed Stimulation Program [40 CFR 146.82(a)(9)]

There are no proposed stimulation programs currently.

Well Construction Procedures [40 CFR 146.82(a)(12)]

New well construction will occur during pre-operational testing, and no abnormal drilling and completion challenges are anticipated. The drilling histories of nearby wells provide key information to drilling professionals and identify the expected conditions to be encountered. The wells will be constructed with objectives to achieve target CO_2 injection rates, to prevent migration of fluids out of the [redacted] and to allow for monitoring, as described by the following:

- Well designs will be sufficient to withstand all anticipated load cases including safety factors.
- Multiple cemented casing strings will protect shallow USDW-bearing zones from contacting injection fluid.
- All casing strings will be cemented in place with volume sufficient to place cement to surface using industry-proven recommended practices for slurry design and placement
- Cement bond logging (CBL) will be used to verify presence of cement in the production casing annulus through and above the confining layer.
- Mechanical integrity testing (MIT) will be performed on the tubing and the tubing/casing annulus.
- Upper completion design enables monitoring devices to be installed downhole, cased hole logs to be acquired and MIT to be conducted.
- All wellhead equipment and downhole tubulars will be designed to accommodate the dimensions necessary for deployment of monitoring equipment such as wireline-conveyed logging tools and sampling devices.

- Realtime surface monitoring equipment with remote connectivity to a centralized facility and alarms provides continual awareness to potential anomalous injection conditions
- Annular fluid (packer fluid) density and additives to mitigate corrosion provide additional protection against mechanical or chemical failure of production casing and upper completion equipment

Well materials utilized will be compatible with the CO_2 injectate and will limit corrosion.

- Wellhead – stainless steel or other corrosion resistant alloy
- Casing – 13Cr L-80 or other appropriate alloy in specified sections of production string (ie. flow-wetted casing)
- Cement – Portland cement has been used extensively in enhanced oil recovery (EOR) injectors. Data acquired from existing wells supports that the materials are compatible with CO_2 where good cement bond between formation and casing exists.
- Tubing – 13Cr L-80 or other corrosion resistant alloy
- Packer – corrosion resistant alloy and hardened elastomer

Well materials follow the following standards:

- API Spec 6/CT ISO 11960 – Specifications for Casing and Tubing
- API Spec 10A/ISO 10426-1 – Specifications for Cements and Materials for Cementing
- API Spec 11D1/ISO 14310 – Downhole Equipment – Packers and Bridge Plugs

Casing and Cementing

The casing specification in Appendix C-1: Injection and Monitoring Well Schematics are sufficient to meet the requirements of 40 CFR 146.86(b)(1)(iv) and to allow for the safe operation at bottomhole injection conditions that will not exceed the maximum allowable operating pressure (MAOP) of 0.63 psi/ft, specified in the Appendix: Operating Procedures and to be confirmed during pre-operational testing.

[redacted]. Standard cementing and casing best practices are sufficient to ensure successful placement and isolation. Industry standard practices and procedures for designing and placing primary cement in the casing annuli will be utilized to ensure mechanical integrity of cement and casing. Staged cementing is not an anticipated requirement.

Operational parameters acquired throughout the cementing operation will be used to compare modeled versus actual pressure and rate. The presence of circulated cement at surface will also be a primary indicator of effective cement placement. Cement evaluation logging will be conducted to confirm cement placement and isolation.

Tubing and Packer

The information in the tables provided in Appendix C-1: Injection and Monitoring Well Schematics is representative of completion equipment that will be used and meets the requirements at 40 CFR

146.86(c). Tubing and packer selection and specifications will be determined prior to completion or conversion during pre-operational testing.

Pre-Injection Testing Plan – Recompletion of Existing Injection Wells

The following tests and logs will be provided from existing records if available or acquired during recompletion in accordance with the testing required under 40 CFR 146.87(a) – (e). Alternative methods may be requested for approval by the Director, and a descriptive report by a qualified log analyst will be submitted to the Director. The testing activities described in this attachment are restricted to the pre-injection phase. Testing and monitoring activities during the injection and post-injection phases are described in Attachment C.

Deviation Checks

Deviation measurements will be surveyed throughout the entirety of the wellbore using a gyro service conveyed on cased hole wireline.

Tests and Logs

Demonstration of Mechanical Integrity

Below is a summary of the tests to be performed prior to CO_2 injection:

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR 146.89(a)(1)	MIT - Internal	SAPT	Prior to operation
40 CFR 146.87(a)(4)	MIT - External	Temperature Log	Prior to operation

Annulus Pressure Test Procedures

1. The tubing/casing annulus (annulus) will be filled with liquid. The volume of fluid required will be measured.

2. Temperature stabilization of the well and annulus liquid is necessary prior to conducting the test.

3. After stabilization, the annulus of the well will be pressurized to a surface pressure of no less equal to or greater than the highest annular pressure specified in the Operating Procedures document. Following pressurization, the annular system must be isolated from the source (annulus tank) by a closed valve.

4. The annulus system must remain isolated for a period of no less than 60 minutes. During the period of isolation, measurements of pressure will be made at ten-minute intervals. The annulus system must remain isolated for a period of no less than 60 minutes. During the period of isolation, measurements of pressure will be made at ten-minute intervals.

CTV will notify the EPA at least 30 days prior to conducting the test and provide a detailed description of the testing procedure. Notification and the opportunity to witness these tests/logs shall be provided to EPA at least 48 hours in advance of a given test/log.

Injectivity and Pressure Fall-Off Testing for Injection Wells

Injectivity testing using brine compatible with formation fluids and formation mineralogy will provide assurance of wellbore connectivity with the reservoir and can be used to forecast CO_2 injection rate. The benefit of completing a pressure fall-off test is to assess injectivity, reservoir flow boundary distances and reservoir pressures. CTV will complete injectivity and pressure fall off testing prior to CO_2 injection, pursuant to 40 CFR §146.87(e).

CTV will consider pressure fall-off testing throughout the injection phase to complement reservoir monitoring if injection rate decreases along with a simultaneous injection pressure increase outside the results from computational modeling.

Pressure fall-off testing procedures are described below:

1. Injection rate will be held constant prior to shut in. The injection rate will be high enough to produce a pressure buildup that will result in valid test data. The maximum operating pressure will not be exceeded.

2. Upon shutting in the injector, surface and bottom-hole pressure and temperature measurements will be taken continuously. If there are offset injectors, rates will be held constant and recorded during the test.

3. The fall-off portion of the test will be conducted for a length of time sufficient that the pressure is no longer influenced by wellbore storage or skin.

A surface gauge at the wellhead and a downhole gauge set above the packer with real-time surface readout capability will be used for the pressure falloff test. Each gauge will meet or exceed ASME B 40.1 Class 2A that provides 0.5% accuracy.

Pre-Injection Testing Plan – Monitoring Wells

The M-1 monitoring well proposed for the CTV storage project will be drilled prior to CO_2 injection. [redacted]. CTV will install monitoring equipment and ensure well integrity in the well construction and completion process. The testing activities described in this attachment are restricted to the pre-injection phase. Testing and monitoring activities during the injection and post-injection phases are described in Attachment C.

Deviation Checks

Deviation measurements for M-1 will be recorded approximately every 120' while drilling the well. For existing wells without deviation surveys, deviation measurements will be surveyed throughout the entirety of the wellbore using a gyro service conveyed on cased hole wireline.

Tests and Logs

The following logs will be acquired during the drilling and prior to the completion of the M-1 well:

- Dual Induction Laterolog
- Spontaneous Potential
- Gamma Ray
- Caliper
- Compensated Neutron
- Formation Density

[redacted]

Demonstration of Mechanical Integrity

CTV will run mechanical integrity logs and tests prior to CO_2 injection operations.

Annulus Pressure Test Procedures

1. The tubing/casing annulus (annulus) will be filled with liquid. The volume of fluid required will be measured.

2. Temperature stabilization of the well and annulus liquid will be verified prior to conducting the test.

3. The annulus of the well will be pressurized to a surface pressure of no less than 500 PSI. Following pressurization, the annular system will be isolated from the source (annulus tank) by a closed valve.

4. The annulus system must remain isolated for a period of no less than 60 minutes. During the period of isolation, measurements of pressure will be made at ten-minute intervals.

Pre-Injection Testing Plan – USDW Monitoring Wells:

The USDW monitoring well proposed for the CTV storage project will be drilled prior to CO_2 injection. CTV will ensure well integrity in the well construction and completion process. The testing activities described in this attachment are restricted to the pre-injection phase. Testing and monitoring activities during the injection and post-injection phases are described in Attachment C.

Deviation Checks

Deviation measurements will be recorded approximately every 120' for each well during construction of the well.

Tests and Logs

The following logs will be acquired during the drilling and prior to the completion of these wells:

- Dual Induction Laterolog
- Spontaneous Potential
- Gamma Ray
- Caliper
- Compensated Neutron
- Formation Density
- Acoustic Cement Bond Log

Demonstration of Mechanical Integrity

CTV will pressure test the casing before perforating and baseline sampling, prior to CO_2 injection operations.